

Evaluation of Powdery Mildew Tolerance in Pumpkin in Central Kentucky

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Introduction

Powdery mildew is a serious disease of cucurbits in Kentucky. The effects of powdery mildew in pumpkins can be devastating, as hot and dry conditions in summer and early fall are generally favorable for outbreaks that can be quite severe. Large outbreaks of powdery mildew can destroy foliage resulting in plants that are unable to support large fruit loads, thus reducing yields. In addition, powdery mildew can spread from the stem and foliage of pumpkin plants to the handles, compromising keeping quality and resulting in unmarketable fruit. For these reasons, pumpkin growers must rely on regularly scheduled fungicide sprays to reduce damage from powdery mildew. The cost of fungicide programs can be relatively high depending on the materials used and the number of times they are applied. In addition, many seed companies offer a number of pumpkin varieties with varying amounts resistance to powdery mildew. When used in combination with fungicide sprays, these varieties enable growers to effectively control powdery mildew on pumpkins. Growers may be able to reduce the number of fungicide sprays required for adequate control of powdery mildew, along with the associated expense, if they choose a variety with high resistance to powdery mildew compared to a variety with minimal resistance. Also, effective disease control can be achieved with less expensive protectant fungicides if varieties with good resistance to powdery mildew are planted. To gain a better understanding of the inherent resistance to powdery mildew in commercially available and experimental pumpkins, 24 varieties of medium and large pumpkins with at least some resistance to powdery mildew were tested without fungicide sprays to determine the level of resistance in each when subjected to high disease pressure. Four pumpkin varieties without any reported powdery mildew resistance were included as positive controls.

Materials and Methods

Pumpkins were direct seeded into bare-ground raised beds on June 6. Beds were spaced on 12-foot centers and plants were seeded at 4-foot within row spacing. Four seeds were placed in each hole (hill) and later thinned to two plants per hill. Each plot consisted of eight plants (four hills) and plots were separated by 12 feet within rows. Drip irrigation tape was placed on the surface of each bed to provide supplemental water. Approximately 50 lb N/A was incorporated preplant using ammonium nitrate. Plants were watered as needed during growth. After seedling establishment, plants were fertigated weekly with ammonium nitrate at a rate of 10 lb/A until mid-August, such that the total (preplant + fertigation) N application for the season was 110 lb/A. Based on soil tests, no additional phosphorous or potassium fertility was necessary.

Weed Control

Plots were sprayed using recommended rates (ID-36), with a combination of Command (clomazone) and Curbit (ethalfluralin) herbicides between rows shortly after plant emergence to

control weed growth. Plots were spot-sprayed with Paraquat (gramoxone) herbicide to control some weeds near plants. Rows were hand-cultivated as needed after vines began to run.

Fungicide Sprays

No fungicides were used during this study.

Insecticide Sprays

Admire (imidacloprid) was applied to the soil surrounding seeds at the time of seeding for control of cucumber beetles. Capture (bifenthrin) was applied at approximately 10 and 12 weeks after seeding to control squash bugs and cucumber beetles.

Plants were routinely monitored for the presence of powdery mildew after seedling emergence. The first signs of powdery mildew infection were detected on July 28. Subsequently, powdery mildew evaluations were conducted weekly beginning August 6, and concluded on August 22. Plants were evaluated using a 0-5 scale where 0=no symptoms, 1=1%, 2=10%, 3=30%, 4=60%, and 5=100% of the upper and lower canopy with symptoms of powdery mildew. Ratings for each plot were converted to percent diseased leaf area using the following transformation: $1.5625 - (5.625 * x) + (5.0625 * x^2)$, where x = assigned rating. Stems were evaluated for powdery mildew at harvest using the same 0-5 scale; however, data were not transformed to percent diseased area.

Fruit were harvested on September 8. Fruit were counted and weighed, and unmarketable fruit were culled. Yields and fruit per acre were based on an estimated plant population of 1,800 plants per acre. Fruit color was assessed using Royal Horticultural Society color chips from the “greyed-orange” group. Stem quality was also assessed at this time. Stem quality was evaluated on a scale of 1 (best)-5 (poor). Stem quality was composed of an aggregate of traits including: stem color, thickness, attachment, and overall attractiveness.

Results and Discussion

Yield and Quality

Yield and quality of all of the varieties tested were likely affected by the high levels of powdery mildew present in this study. However, the following results demonstrate the relative performance of one variety compared to another when grown under high powdery mildew pressure.

Conestoga Giant, Super Herc, Dependable, and Summit all had an average fruit weight of more than 20 pounds (Table 1). This is expected, as all are marketed as larger fruited pumpkins. Of these larger pumpkins, Summit and Super Herc had the highest marketable yields per acre (Table 2). Merlin, a medium size pumpkin (13.7 lb/fruit), had the greatest marketable yields. This was primarily due to the large number of fruit per acre (3,600) that it produced. Magic Lantern, a very popular variety in Kentucky, is another medium (14.2 lb/fruit) sized pumpkin that yielded well, produced a low number of culls, and had moderate powdery mildew resistance. Other noteworthy varieties were Gladiator and Warlock. Both varieties had good yields, a relatively low percentage of culls, excellent dark orange color, and high quality stems, in addition to displaying moderate resistance to powdery mildew. Some fruit from Warlock can be a little “warty” which may or may not be suitable for some markets.

Other varieties that yielded well and had a moderate-high level of resistance to powdery mildew (see below) included HSR4710 and Camaro. Camaro and HSR4720 produced medium/large

fruit, 17.2 and 20.3 lbs/fruit, respectively, had excellent resistance to powdery mildew, and had good stem ratings. The colors of both pumpkins however were a pale yellow-orange, in contrast to a more typical medium orange color of a Howden type pumpkin.

Powdery Mildew Resistance

The varieties tested in the study showed varying levels of resistance to powdery mildew, ranging from none to moderate-high (Table 3). At the earliest evaluation (August 6), eight varieties, including Camaro, HSR 4710, Gladiator, Warlock, and Magic Wand, had 20% or less of total leaf area (diseased leaf area, or DLA) affected by powdery mildew. By the final evaluation (August 22), all varieties had 50% or more DLA; Camaro showed 59% DLA, making it the variety with the greatest resistance to powdery mildew in the trial. Seasonlong severity of powdery mildew, determined by calculating the area under disease progress curves (AUDPC) for each variety, was lowest for Camaro, HSR 4710, HSR 4721, Gladiator, and Warlock. Varieties such as Checkmate, ACX 7301, ACX 7302, ACX 6501, Dependable, Howden, and King Midas showed the least resistance to powdery mildew in the trial. Severity of powdery mildew on pumpkin stems appeared to be linked to foliar disease severity. In general, varieties with greater resistance to powdery mildew on foliage tended to have less powdery mildew on stems than varieties with lower foliar resistance to the disease.

For many of the pumpkin varieties tested, our results appear to agree with the resistance ratings reported by seed companies. For example, varieties reported to be “highly resistant” (Camaro, HSR 4710, HSR 4721, Gladiator) ranked as the most resistant in our trial. Varieties reported to have intermediate resistance, however, showed a wide range of powdery mildew resistance in the current study that ranged from moderate-high (Warlock, Magic Lantern) to low (Hannibal, King Midas). One variety, Hannibal, was described as “moderately tolerant” to powdery mildew, but performed no better than completely susceptible varieties. Those varieties reported to be completely susceptible to powdery mildew, for the most part, tended to have the highest severity of disease in this trial. These results demonstrate the variability between advertised and actual resistance to powdery mildew in the varieties that were evaluated. It is important to remember that disease pressure will be different between years and locations, and our findings represent a single trial in a high-pressure year. Variety performance could be better or worse, depending on disease pressure, but the relative rankings between varieties would not be expected to change greatly.

Our results suggest that there are varieties with good yields and moderate levels of powdery mildew resistance. Growing these varieties might enable a grower to reduce fungicide inputs and associated costs while still producing good marketable yields of pumpkins.

Table 1. Seed source, predicted days to harvest, average fruit weight, stem ratings, and color evaluations for 28 varieties of pumpkins grown in Lexington, KY in 2008¹.

Variety	Seed Source ²	Avg. Fruit Wt. (lbs)	Stem Rating (1-5) ³	Color	Color (RHC Code) ⁴		
Conestoga Giant	SI	23.2	a	3.2	bcde	<i>medium orange</i>	N163B
Super Herc.	HM	23.2	a	1.3	h	<i>medium orange</i>	N163B
Dependable	AC	22.1	ab	3.3	abcd	<i>yellow orange</i>	N163C
Summit	OUT	20.8	abc	2.3	defg	<i>medium orange</i>	N163B
HSR 4710	HL	20.3	abcd	3.3	abcd	<i>yellow orange</i>	N163C
Aladdin	HM	19.5	bcd	3.7	ab	<i>medium orange</i>	N163B
Checkmate	OUT	19.5	bcd	2.0	fgh	<i>medium orange</i>	N163B
King Midas	SI	18.8	bcde	3.3	abcd	<i>medium orange</i>	N163B
Camaro	HL/SW	17.2	cdef	2.6	cdef	<i>yellow orange</i>	N163C
Spartan	SW	17.0	def	2.3	efgh	<i>dark orange</i>	N172B
Howden	SW	16.8	def	2.8	bcdef	<i>medium orange</i>	N163B
ACX7302	AC	15.5	efg	3.7	ab	<i>medium orange (variable)</i>	N172C
ACX6501	AC	15.2	fgh	3.5	abc	<i>yellow orange</i>	N163C
Warlock	HM	15.1	fgh	2.3	efgh	<i>dark orange</i>	N172B
20 Karat Gold	RU	14.6	fgh	2.8	bcdef	<i>medium orange</i>	N163B
Hannibal	SI	14.3	fghi	3.0	bcde	<i>medium deep orange</i>	N172C
Magic Lantern	HM	14.2	fghi	2.3	efgh	<i>medium deep orange</i>	N172C
Sorcerer	HM	14.1	fghij	2.9	bcdef	<i>medium orange</i>	N163B
Gladiator	HM	14.1	fghij	1.7	gh	<i>dark orange</i>	N172B
ACX7301	AC	13.9	fghij	3.6	ab	<i>medium orange</i>	N163B
Superior	OUT	13.9	fghij	3.1	bcde	<i>medium orange</i>	N163B
Merlin	HM	13.7	fghij	2.8	bcdef	<i>medium orange</i>	N163B
Magic Wand	HM	13.2	ghij	1.6	gh	<i>medium deep orange</i>	N172C
Charisma	JS	11.7	hijk	3.5	abc	<i>yellow orange</i>	N163C
Magician	HM	11.7	hijk	3.0	bcde	<i>medium deep orange</i>	N172C
Capital	OUT	11.0	ijk	2.9	bcdef	<i>medium orange</i>	N163B
Pankow's Field	H	10.6	jk	4.1	a	<i>yellow orange</i>	N163C
HSR4721	HL	9.5	k	3.2	bcde	<i>yellow orange</i>	N163C

¹Means in the same column followed by different letters were significantly different at $P < 0.05$.

²Seed sources found in Appendix A.

³Stem rating (1=best, 5=worst). Stem ratings based on stem color, architecture, thickness and attachment, and overall attractiveness.

⁴Royal Horticulture Society (RHC) color chip codes were used to objectively identify colors of the pumpkins. The predominant color chip matching each variety is listed. Both chips were part of the "Greyed-Orange" Group.

Table 2. Total yield, fruit per acre, marketable yield, marketable fruit per acre, and percentage of culls for 28 medium-large size pumpkins grown in Lexington, KY in 2008. Varieties are ordered based on marketable yield (highest to lowest)¹.

Variety	Total Yield (cwt/A) ²		Avg. No Fruit/A		Marketable Yield (cwt/A)		Marketable Yield (Fruit/A)		Culls (%) ³	
Merlin	483	a	3600	ab	461	a	3375	a	5.7	defg
Magic Lantern	473	ab	3450	abc	447	a	3150	ab	5.3	efg
HSR4721	293	de	3225	abcd	291	bcde	3150	ab	2.0	fg
Gladiator	423	abcd	3000	abcdef	423	ab	3000	abc	0.0	g
Capital	320	cde	2925	abcdefg	298	bcde	2700	abcd	6.2	defg
Warlock	398	abcd	2643	cdefghi	385	abc	2531	bcde	4.0	egf
Magic Wand	338	bcde	2588	cdefghi	327	abcd	2475	bcdef	3.0	efg
Superior	435	abcd	3543	ab	330	abcd	2419	bcdefg	23.2	abcde
Sorcerer	418	abcd	3318	abc	337	abcd	2363	cdefg	20.5	abcdef
ACX6501	480	ab	3675	a	349	abcd	2325	cdefgh	27.7	abc
Magician	328	cde	3038	abcde	258	cde	2138	cdefghi	24.0	abcde
Summit	477	ab	2400	defghi	424	ab	2025	defghij	12.3	bcdefg
ACX7301	440	abc	3600	ab	275	cde	1969	defghij	37.8	a
20 Karat Gold	307	cde	2325	efghi	280	cde	1950	defghijk	8.3	cdefg
HSR 4710	405	abcd	2193	fghi	379	abc	1913	efghijk	4.8	efg
Charisma	305	cde	2868	abcdefg	223	de	1913	efghijk	26.8	abcd
Camaro	315	cde	1856	i	301	bcd	1744	fghijk	5.0	efg
ACX7302	393	abcd	2775	bcdefgh	268	cde	1725	fghijk	31.0	ab
Spartan	338	bcde	2138	fghi	286	bcde	1688	ghijk	14.8	bcdefg
Howden	303	cde	1875	i	257	cde	1575	hijk	12.7	bcdefg
Pankow's Field	198	e	2081	ghi	156	e	1519	ijk	21.2	abcdef
Super Herc.	423	abcd	1950	hi	351	abcd	1500	ijk	17.7	bcdefg
Aladdin	350	abcd	1875	i	292	bcde	1500	ijk	16.7	bcdefg
Hannibal	310	cde	2250	efghi	220	de	1500	ijk	31.0	a
Dependable	440	abc	2306	efghi	302	bcd	1463	ijk	28.5	abc
King Midas	417	abcd	2625	cdefghi	266	cde	1425	ijk	30.3	ab
Checkmate	340	abcde	1912	hi	248	cde	1294	jk	29.0	abc
Conestoga Giant	410	abcd	1875	i	275	cde	1200	k	17.0	bcdefg

¹Means in the same column followed by different letters were significantly different at $P < 0.05$.

²cwt/A=100 lb weight/acre, based on a plant population of 1,800 plants per acre.

³% cull based on weight of nonmarketable pumpkins/total yield of pumpkins.

Table 3. Severity of powdery mildew on 28 medium-large size pumpkins grown in Lexington, KY in 2008. Varieties are ordered based on overall disease severity (lowest to highest).

Variety	PM ¹ Res.	Powdery Mildew (PM) Severity ²						Overall PM Severity		Stem Rating	
		% DLA (8/6/08)		% DLA (8/15/08)		% DLA (8/22/08)		(AUDPC) ³		(0-5) ⁴	
Camaro	HR	7.1	k ⁵	22.1	i	58.6	g	463.8	n	1.25	k
HSR 4710	HR	9.8	k	38.5	h	75.1	ef	683.4	m	1.75	jk
HSR4721	HR	14.2	jk	39.7	gh	71.1	f	729.7	lm	1.75	jk
Gladiator	HR	17.3	hij	35.1	h	74.2	ef	739.8	klm	1.25	k
Warlock	IR	11.6	ijk	52.5	fg	81.9	de	840.6	jkl	1.50	jk
Magic Wand	IR	19.0	hi	52.3	fg	86.3	cd	938.6	ijk	1.75	jk
Magician	IR	16.6	hij	66.9	def	89.1	bcd	1,038.7	hij	1.75	jk
Superior	IR	20.3	gh	61.7	ef	94.7	abc	1,058.9	g-j	1.50	jk
Magic Lantern	IR	23.4	gh	66.6	b-f	96.6	abc	1,139.9	ghi	1.75	jk
Summit	IR	29.4	gh	63.1	fg	89.9	a-d	1,157.1	hij	1.63	jk
Capital	IR	34.6	efg	62.4	c-f	94.0	abc	1,225.9	fgh	1.88	ijk
Spartan	IR	29.9	fg	82.6	a-d	100	a	1,355.0	efg	2.13	hij
Aladdin	IR	38.6	def	83.0	abc	100	a	1,457.6	def	1.88	ijk
Merlin	IR	41.3	def	80.5	a-e	100	a	1,469.3	def	1.88	ijk
Charisma	IR	44.3	b-f	80.4	a-e	100	a	1,502.4	def	1.75	jk
Super Herc.	IR	55.9	a-e	76.7	a-e	97.3	ab	1,597.0	cde	2.50	ghi
20 Karat Gold	IR	41.9	c-f	98.6	a	97.3	ab	1,611.5	b-e	3.25	c-f
Sorcerer	NR	51.0	a-e	93.3	a	99.3	a	1,680.9	a-e	2.75	fgh
Conestoga Giant	IR	56.4	a-e	86.2	ab	99.3	a	1,686.3	a-e	2.50	ghi
Hannibal	IR	55.0	a-e	89.9	a	97.3	ab	1,692.7	a-e	3.88	abc
King Midas	IR	57.3	a-e	100	a	100	a	1,809.4	a-d	3.0	d-g
Howden	NR	69.3	a-d	93.5	a	100	a	1,894.8	a-d	3.50	a-e
Pankow's Field	NR	74.1	ab	93.4	a	100	a	1,949.2	abc	4.0	ab
ACX6501	UN	69.9	abc	100	a	100	a	1,953.7	abc	3.63	a-d
Dependable	MT	79.5	a	97.4	a	100	a	2,042.7	ab	3.38	b-f
ACX7302	UN	83.9	a	92.1	a	98.6	a	2,047.6	ab	3.63	a-d
ACX7301	UN	83.0	a	94.6	a	99.3	a	2,059.0	ab	4.13	a
Checkmate	NR	83.5	a	97.4	a	100	a	2,089.2	a	2.88	efg

¹Reported resistance to powdery mildew (PM) according to seed company sources. UN=unknown, NR=no resistance, MT=mild tolerance, IR=intermediate resistance, and HR=high resistance.

²Severity of powdery mildew assessed as the percentage of diseased leaf area (DLA).

³Overall (seasonlong) severity of powdery mildew as determined by the area under disease progress curves (AUDPC) calculated from severity ratings taken on August 6, 15, and 22.

⁴Severity of powdery mildew on stems evaluated at harvest using a 0-5 scale, where 0=no disease, 1=1%, 2=10%, 3=30%, 4=6%, and 5=100% of stem area diseased.

⁵Means in the same column followed by the same letter do not differ significantly as determined by Fisher's protected LSD test ($P \leq 0.05$). Statistics for foliar disease severity were calculated on arcsin-transformed means; non-transformed means are reported in the table.